PROBLEMS OF PHYSIOGRAPHY CONCERNING SALINITY AND TEMPERATURE OF THE PACIFIC OCEAN.*

BERING SEA.

DIAGRAM No. 1 shows the mean temperatures and densities in the deeper parts of Bering Sea to the southward of the Pribilof Islands. It will be noticed that the density increases from 1.0241 at the surface to 1.0257 at the depth of 1,000 fathoms and according to a single observation to 1.0261 in 1998 fathoms at the bottom of the sea. We attribute the low density at the surface to a copious precipitation and to the discharge of several large rivers, notably the Yukon. This tendency towards a decrease of the density is counteracted by an undercurrent from the Northwest Pacific which carries a supply of salt. The relation of the Mediterranean Sea to the Atlantic Ocean furnishes an instructive illustration of the way in which salt and heat are conveyed from one sea to another; the same salt which is carried into the Mediterranean by a surface current is taken out again by a warm undercurrent which spreads out over an area extending from Gibraltar to beyond the middle of the Atlantic and, at the same time, sinks to depths below 1,500 fathoms. The Kuro Siwo, the great carrier of salt and heat in the North Pacific, does not, as a surface current, reach beyond 42 of Latitude, whence it passes northward beneath the surface, losing both heat and salt by its contact with colder and lighter water, and continues to sink as it advances until in the noted accumulation of salt in the deeper parts of Bering Sea we recognize the last traces of that warm and briny current. Lieut. Comm'dr Moser in 1896 found the depth of the channel between Bering Island and Kamchatka to be 3,117 fathoms instead of less than 500, as has been here-

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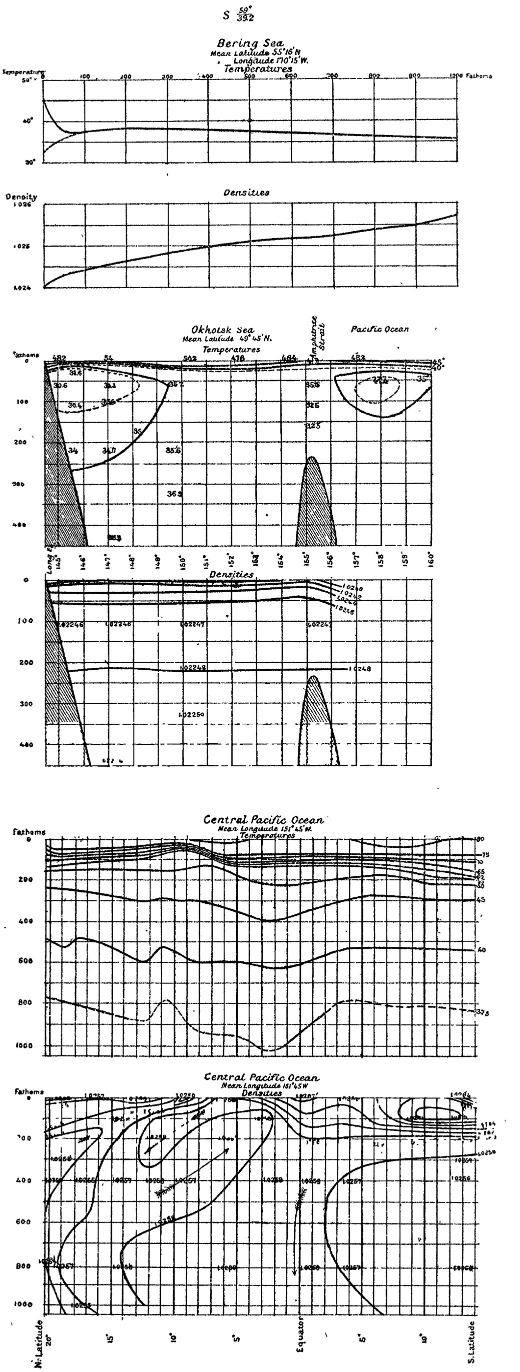
Diagrams illustrating Temperature and Density of the Pacific Ocean



tofore assumed. We may admit that this great depth, as well as that of nearly 2,000 fathoms between Bering Island and the Aleutian Islands, to some extent facilitates the ingress of the waters of the Pacific, but in the matter of transfer of salt from one sea to another an ample supply of this substance is more essential than great depth of connecting channel. The Strait of Gibraltar, which, as we have seen elsewhere, regulates the density of not only the Mediterranean, but also of a large part of the Atlantic, has the moderate depth of 170 fathoms.

The temperature curve shows a minimum of 37°.5 in 100 fathoms; this indicates that the heat which is transmitted from the surface does not descend below that limit and that whatever heat we find at greater depths has been conveyed by the same undercurrent which carried the salt. There is considerable difference in the bottom temperatures of the great depths; they vary from 34° to 35° and are perhaps slightly below those of the Pacific. We fail to notice any indications of a constant temperature below a certain depth, such as we find in the Caribbean Sea and Gulf of Mexico, where the thermometer registers 39°.5 at all depths exceeding 700 fathoms. The observations on which the temperature curve is based were made about the middle of August, when the summer heat had nearly reached its maximum; the broken line indicates the probable conditions at the end of February, when the surface temperature is supposed to remain near the freezing point of fresh water.

THE OKHOTSK SEA.

IN the Diagram giving an east and west section through the Okhotsk Sea we notice in the western part the existence of a thick layer of very cold water at a short distance below the surface, covered by a stratum of very low density but of comparatively high temperature. When we recall that sea water does not commence to congeal until its temperature is reduced to below 29° this cold layer furnishes an indication of the severity of a Siberian winter, when the whole of Okhotsk Sea is frozen over. The low density of the surface water is due to the fact that it is composed partly of melted ice, which does not contain much salt, and partly of river water, particularly that of the Amur, which, after rounding the northern point of Saghalin Island, floats southward along its eastern shore. It is rather surprising to find such steep gradients in the temperatures as 54° at the surface and 31° in 26 fathoms, and they can be accounted for only by assuming that there are no strong currents which keep the water agitated, and furthermore that, whatever the increased percentage of salt in consequence of evaporation may be, it is too small to sink the surface water to any considerable depth.

There are no temperature observations available for the water under the surface in the eastern part of Okhotsk Sea except bottom temperatures; we conjecture that during the winter months there is but little difference between the temperatures of the eastern and western part. In the height of summer, however, we may expect to find about 35°.2 the lowest temperature at a depth of about 100 fathoms in the eastern part. At greater depths a slight increase of temperature is noticed, 36°.3 is recorded at 328 and 437 fathoms, and there appears to be a nearly uniform temperature of 36° in the great depths of the basin, which, according to Moser's soundings in 1896, has the shape of a trough with a steep slope from the Kuril Islands, and depths exceeding 1,800 fathoms. The densities increase from 1.0222–1.0240 at the surface to 1.0246 at 55 fathoms and 1.0248 at 219 and 1.0254 at 437 fathoms. These relations of density and temperature are similar to those of Bering Sea, showing a continuous increase of density from the surface downward and

the existence of a minimum of temperature at the depth of about 100 fathoms, separating the much warmer surface waters from the slightly warmer deeper waters. Hence Okhotsk Sea, like Bering Sea, must receive a supply of salt and heat from a connecting sea by a current which starts at the surface and during its progress gradually sinks to the greatest depths. The Okhotsk Sea connects with the Japan Sea by La Pérouse Strait and with the Pacific by the Passages through the Kurils, and it may receive its supply of salt from either of these seas, but the observations by Makaroff in 1887 and Moser in 1896 point towards the Japan Sea as the source. Makaroff found in La Pérouse Strait three kinds of water, each of a distinctive physical character. In the southern part he found dense and warm water, with indications that it was from the Japan Sea on its northward way. In the northern part he found warm and light surface water similar to that we encounter farther north, off the shore of Saghalin Island; it is probably composed of melted ice and the waters of the Amur and other rivers which have come down from the northward along Saghalin Island. This surface water rests on water which has considerable density but a very low temperature; it is of the same character as that cold stratum which we found underlying the warm surface waters in a higher latitude, and we may, therefore, conclude that along the entire eastern shore of Saghalin Island the water below the depth of 25 fathoms receives but a small increase of temperature in consequence of the summer's warmth. Where it meets the water from the Japan Sea it rises to the surface in a streak which extends from Cape Crillon forty miles in a southeasterly direction, effectually shutting off the Japanese current from the western part of Okhotsk Sea. Moser's density observations show that this current advances northward in the eastern part of the Sea, passing along the Kuril Islands, and that it is gradually overlapped by the lighter water to its left, thus verifying Makaroff's views, according to which the waters from the Japan Sea, after reaching the Okhotsk Sea, continue to sink until they occupy all the deeper parts of this basin. The depth of La Pérouse Strait is but 35 fathoms. The passages through the Kurils are probably much deeper. Makaroff gives 235 fathoms for the Amphitrite Strait, and from Moser's temperature observations, we infer that about 800 fathoms' depth may be carried from the Pacific into the Okhotsk Sea. From this we may conclude that, if the Okhotsk Sea does not receive a supply of salt and heat through an undercurrent from the Pacific, it is not on account of an insufficient depth of channel, but due to a greater difference between the physical condition of the waters of the Okhotsk Sea and those of the Japan Sea than exists between the former and those of the Pacific adjoining. The cold zone along the Kuril Islands was formerly thought to be due to the effect of cold currents which were supposed to come from the neighborhood of Kamchatka, but Makaroff correctly attributes the low temperature to a commingling of the cold water from lower strata with the surface water. There are instances where cold water rises to the surface in consequence of peculiar conditions of density and temperature, as in the case of the cold streak at the equator off the west coast of South America; but in the present case an inspection of the diagram will show that the rising is confined to the upper stratum of 25 fathoms' depth, and that it should be attributed to the bottom configuration, which offers formidable obstructions to the movements of a formidable tidal current sweeping through the passages four times a day.

THE CENTRAL PACIFIC OCEAN.

THE Diagram shows a section of the Pacific

Ocean in the tropics along the meridian of 151° 45′ W., a short distance to the eastward of the Hawaiian Islands. The surface densities in this section, and generally in the South Pacific, are higher than in the North Pacific; this is due mainly to the fact that no large rivers, draining extensive continental areas, empty their waters into the South Pacific. As a rule the densities decrease from the surface to the depth of about 300 fathoms, where densities from 1.0254 to 1.0257 are found; thence there is a very gradual increase to the bottom, where 1.0259 is reached. This depth of 300 fathoms indicates the approximate limit to which salt and heat are carried through the process of surface evaporation. But there is another cause which brings the waters of the ocean into motion and tends to diffuse salt and heat into regions which are not affected directly by evaporation. If two differently constituted bodies of sea-water meet under the conditions of equilibrium, the one composed of dense and warm, the other of light and cold water, an effort towards equalization of the proportions of salt and heat at the plane of contact will develop a tendency in the denser water to sink and in the lighter water to rise to a higher level. The waters of the South Pacific, being denser and warmer in the upper stratum than those of the north Pacific, exhibit this tendency to sink in the vicinity of the equator, where with a density of 1.0259 to 1.0260 at a depth of 200 fathoms they descend to more than 1,000 fathoms' depth. At the same time the light water of the north Pacific rises from the depth of 800 fathoms in latitude 20° N. with a density of 1.0254 in an oblique direction towards the equator, arriving in latitude 3° N. with a density of 1.0258 at 50 fathoms from the surface. The effects of the sinking of the dense and the rising of the cold water are shown in the diagram of temperatures by the high temperatures between the equator and 10° N. latitude at all depths exceeding 150 fathoms and by the existence of a minimum of surface temperature at the equator itself. We note a second example of bodies of water changing their level in the upper left-hand part of the diagram, where dense and warm water from the region of the equatorial counter current undermines the north equatorial current and forces its light and cold water towards the surface. The diagram has the defect of showing motion in only two directions, vertical and meridional, while the third component, the most important one, that in an east-and-west direction is not represented and hitherto has not received our attention. The presence in the south Pacific of water at the depth of 100 fathoms with greater density than is found at the surface cannot be accounted for by mere sinking 'in loco,' but we have to assume that the surface water has drifted to its present position by a current from the eastward, while the lower water comes from a more southerly direction. Likewise, we find in latitude 9° 28′ N. the density of the surface water is 1.0250, and is nowhere less than 1.0256 under the surface; as we cannot admit that in a region where density decreases with depth water rising to the surface should have its density reduced, we must assume that the lightness of the surface water is either due to precipitation or to a current of light water, the north equatorial, and that the water of the density of 1.0256 may not reach the surface, or, if at all, then probably far to the westward of the position indicated on the diagram.

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THE STORING OF PAMPHLETS.

THE question of the best method of keeping pamphlets in a private library has become a question of great practical importance to the scientific worker. Owing to the custom of exchanging reprints of arti-